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Reduction of sodium chloride in bread using encapsulated salt

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Abstract: High salt (sodium chloride) consumption is a significant public health concern worldwide. There is strong scientific evidence that a high-sodium diet is associated with increased rates of several health problems. This article aims to replace the salt content of sliced bread with salt encapsulated in xanthan gum, providing a non-homogeneous distribution of salt to maintain the perception of salty taste. The key focus of this research is to maintain the product's sensory characteristics and ensure consumer acceptance, a crucial aspect in the success of any food product. For this purpose, three sliced bread formulations were developed and compared: Formulation 1 (F1) as the standard, and Formulations 2 (F2) and 3 (F3) using the encapsulated salt technique, with respective reductions of 30% and 50% in salt. Physicochemical analyses were performed on the products of the three bread formulations. Sensory analysis was also performed on the products from the three bread formulations, involving 80 untrained tasters, to evaluate and compare salt intensity. Thus, it was evaluated that F1 and F2 did not present statistical differences in the sodium content, while F3 presented a difference between the others. Therefore, it was possible to conclude that reducing sodium by 29% using xanthan gum encapsulation can be an alternative to reducing salt without lowering flavour perception.

Keywords: non-homogeneous distribution; sensory; xanthan gum

Bread is a widely consumed food worldwide, so the high salt content in bread has been a concern for health authorities and researchers. Breads are products obtained from wheat flour and/or other flours, with added liquid, resulting from the fermentation process or baking, and may contain different ingredients, as long as they do not alter the characteristics of the products.

Bread, along with other bakery products, represents one of the primary sources of energy as well as sodium chloride in the daily Western diet, so many initiatives aimed at reducing salt intake have focused on reducing the salt content of bread (Dischen et al. 2012; Silow et al. 2016)

In particular, it has been reported that cereal products account for about 30% of total salt intake (Lynch et al. 2009). Thus, reducing the salt content in these products could have a substantial positive impact on societal health.

Globally, the average daily salt intake is much higher than the World Health Organisation's recommended level of 5 g per person per day; the current average per person consumption is 9–12 g per day. Thus, excessive sodium intake has been associated with adverse health effects, as sodium is a major contributor to hypertension and cardiovascular disease (Hendriksen et al. 2014; Kloss et al. 2015).

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Salt (NaCl) plays an essential role in food flavour perception. It enhances salinity, intensifies overall flavour, improves aroma perception, and reduces bitterness. Therefore, the amount of salt in a food is a key factor in consumer acceptance (Voinea et al. 2020). Cereal-based products, such as bread, are important sources of sodium in Western countries' diets (Silow et al. 2016). However, reducing salt in bakery products can alter dough structure, compromising its appearance and texture (Guilloux et al. 2015).

Reducing the salt content in processed foods is a major technological and sensory challenge, as it affects not only the product's salty flavour and acceptance but also its functional properties. In bakery products, reducing salt can affect the structure of the dough, compromising its appearance, texture and shelf life (Lynch et al. 2009; Noort et al. 2012; Guilloux et al. 2015; Israr et al. 2016; Silow et al. 2016).

This multifunctional characteristic of salt increases the complexity of reducing sodium in the diet, meaning that reduction strategies should not compromise the perception of food acceptability or its characteristics (Chiu et al. 2017).

According to Chen et al. (2019), salt increases dough mixing resistance, decreases dough viscosity during processing, stabilises yeast fermentation rate, leads to a more attractive crust colour, improves bread texture, delays bread staling, and inhibits microbial growth during bread storage. But indeed, the main contribution of salt in bread is related to flavour (Monteiro et al. 2021).

Therefore, reducing sodium content remains challenging while maintaining bread quality. In addition to its contribution to flavour, sodium plays an important technological role in the bread-making process (Pashaei et al. 2022).

A technology proposed to reduce some components of food without compromising its sensory quality is called 'taste contrast' or 'flavour contrast' (Noort et al. 2010; Beck et al. 2022). Wan et al. (2021) demonstrated that flavour contrast is also verified for sweets, where inhomogeneous yoghurts with high sugar concentration gradients were sweeter than yoghurts with a homogeneous distribution.

Noort et al. (2012) showed that this sensory contrast enabled them to reduce the amount of salt used in bread. In this case, they used encapsulated salt, which, due to its encapsulation, did not dissolve in the dough, resulting in regions with higher and lower salt concentrations.

The flavour contrast technique represents an interesting advancement for the global food industry. In the case of salt, this method enhances the salty taste,

allowing the amount added to the food to be reduced. However, reducing its content in bread is challenging, as salt is essential to the product's taste.

According to Beck et al. (2022), encapsulation technology involves coating a core with a protective medium, enabling the slow release of the core component. In the bread production with contrast technology, encapsulation is particularly useful to ensure that the salt is not distributed homogeneously throughout the dough during its formation.

Studies such as those by Beck et al. (2022), Noort et al. (2012), and Monteiro et al. (2021) used various encapsulating agents such as starches, waxy starches, and carnauba wax to contrast salt in breads, but the authors highlight some disadvantages, such as residual flavours and textures. On the other hand, Mohammadi et al. (2014) emphasise that xanthan gum, in addition to being an excellent thickener, generally does not alter the flavour and other characteristics of breads.

Therefore, this work aims to develop sliced bread with salt encapsulated in xanthan gum, to reduce sodium through non-homogeneous distribution and to maintain the product's sensory properties.

MATERIAL AND METHODS

The ingredients used for the formulations were purchased from supermarkets in Maringá/PR (estado do Paraná/Brazil). The products were prepared in the Food Engineering Cereal Laboratory at the State University of Maringá (UEM).

Three formulations of sliced bread were prepared: Formulation 1 (F1) as the standard, Formulation 2 (F2) with a 30% reduction in sodium, and Formulation 3 (F3) with a 50% reduction in sodium, with salt encapsulated by xanthan gum in F2 and F3.

Preparation of salt crystals encapsulated with xanthan gum. The encapsulated salt consisted of a salt core coated with an encapsulating agent (xanthan gum) to slowly release the salt during mixing and ensure an even distribution. To achieve encapsulation, in Formula 2, the salt content was reduced by 30% compared to Formula 1 and 30% xanthan gum was added. In Formula 3, the salt content was reduced by 50% compared to Formula 1, and 50% xanthan gum was added. For Formula 2, 950 g of water, 35 g of salt, and 15 g of xanthan gum were mixed; in Formula 3, 950 g of water, 25 g of salt, 10 g of cornstarch, and 15 g of xanthan gum were mixed. After mixing at 80 °C for 10 min, the solution was gelatinised entirely and dried in a circulation oven at 60 °C for 48 h. To ensure proper distribution of the salt capsules in the dough, as shown in Figure 1,

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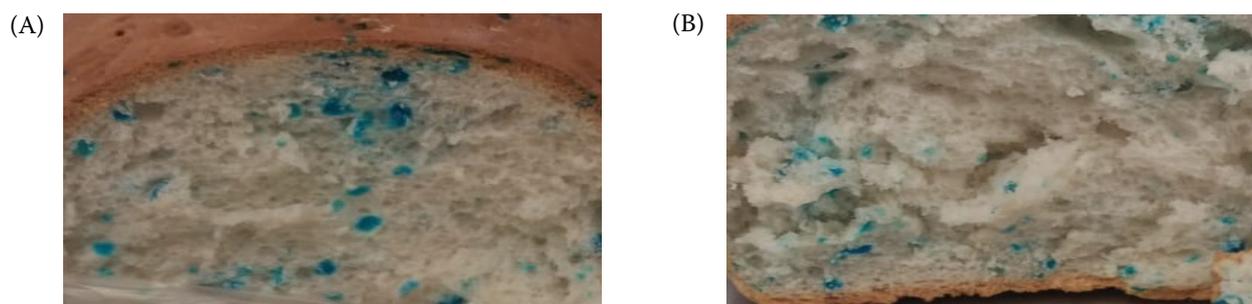


Figure 1. (A) Bread with 50% salt reduction, salt encapsulated with xanthan gum and blue dye; (B) sliced bread produced with 30% salt reduction, salt encapsulated with xanthan gum and blue dye

only in the pre-tests was Arcólor blue food colouring used to prepare the capsules. However, throughout the analysis, especially during the sensory test, the colouring was not used to avoid affecting the product's visual evaluation. After the salt and xanthan gum mixture dried, the material was ground and sieved (Mash 12) and subsequently applied during the dough dividing and shaping phase to check for inhomogeneity.

Preparing the bread. The breads were prepared following the formulation described by Basso et al. (2015), with modifications. The ingredients and their respective proportions are detailed in Table 1.

Each formulation was prepared separately, as shown in Figure 2, following the sequence below: the ingredients were weighed on an analytical balance and mixed in a spiral mixer (Gastromaq MES 25, Caxias, Brazil). Salt (F1) or salt capsules (F2 and F3) were added in the final mixing phase. The equipment was set to the minimum speed, and water at 3 °C was slowly added to the dry ingredients, which were then stirred for 7 min. After the ingredients were homogenised, the dough was stirred rapidly for 2 min. The salt or salt capsules were then added, and the mixture was mixed rapidly for another 2 min. The dough was then shaped into circles and placed in 21 cm × 11 cm aluminium pans greased with partially hydrogenated

vegetable shortening. Fermentation was carried out by allowing the dough to rest in a BOD incubator at 40% humidity and 32 °C for 50 min.

The breads were baked for 35 min at 180 °C, without steam injection, in a 10-gauge turbo gas oven (Gpaniz, Brazil). They were then removed from the moulds and kept at room temperature until they could be stored in plastic bags before analysis.

Analysis of breads. The bread was evaluated for sodium content using method 972.29 (AOAC 1990), moisture content using methodology 930.15 (AOAC 2005), pH was evaluated by an electrometric process with a digital potentiometer (Hanna, model HI 221), water activity was performed using the portable meter model Aw 4TE. The specific volume of the bread was determined by the millet seed displacement method and calculated by the ratio of the volume of the bread (mL) to the bread mass (g) (Parenti et al. 2020), sodium analyses were performed in triplicate.

The breadcrumb colour was evaluated at 25 °C in an environment illuminated by white light, using the optical Chroma Meter CR-400 coupled to the CR-A33d probe, with three flashes (Konica Minolta, Japan). The parameter ΔE^* (Equation 1) determined the colour difference between treatments. Colour analyses

Table 1. Formulation of the sliced breads produced (g) (mean ± SD)

Ingredient	F1	F2	F3
Wheat flour	1 000	1 000	1 000
Water at a temperature of 3 °C	550	550	550
Refined sugar	50	50	50
Partial hydrogenated vegetable fat	40	40	40
Salt or encapsulated salt	20	20	20
Dry biological yeast	25	25	25
Equivalent amount of salt	20	14	10

F1 – standard formulation; F2 – 30% sodium reduction; F3 – 50% sodium reduction



Figure 2. Bread-making flowchart

were performed at 3 random points of 3 samples from each treatment.

$$\Delta E^* = \sqrt{[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]} \quad (1)$$

where: ΔL^* – the variation in brightness of each sample about the control, ranging from dark to light; Δa^* – the difference in hue between the sample and the control, ranging from red ($+a^*$) to green ($-a^*$); Δb^* – the colour variation between the sample and the control, ranging from yellow ($+b^*$) to blue ($-b^*$).

Sensory analysis was performed with 80 untrained tasters using an unstructured 7 cm scale to evaluate salt intensity for each sample. The judges received a portion of each sample (approximately 10 g); each sample was coded with random three-digit numbers and accompanied by a glass of water, with approval from the Research Ethics Committee of the State University of Maringá (CAAE 18718013.3.0000.0104).

Untrained consumers served as evaluators, representing the product's target audience and yielding more representative results than those obtained by experts (Vieira et al. 2020; Monteiro et al. 2021). Therefore, due to the greater variability of responses, more tasters were used than would be necessary if trained tasters were chosen.

The data were statistically analysed using Analysis of Variance (ANOVA), and the means were compared using the Tukey test at a significance level of 5%.

RESULTS AND DISCUSSION

Table 2 presents the results of moisture, water activity (A_w), pH, specific volume and shrinkage index of the bread.

The average moisture content of the standard and reduced-sodium sliced bread differed by 29.66% and 34.68%, respectively. However, they do not show differences between the values found in the literature (Silow et al. 2016; Beck et al. 2022), these differences, as found in the literature, should be caused only by differences in heat distribution during baking.

Regarding water activity (A_w), F2 (0.90 ± 0.00) showed a significant difference from F1 (0.93 ± 0.00) and F3 (0.93 ± 0.00); these differences probably stem from the same variation in heat distribution that affects moisture content. The water activity (A_w) indicates the amount of water available to support molecular movement, transformations, and microbial growth.

Sliced bread is a product with high water activity; it has a lot of free water available for microbial growth and chemical reactions that deteriorate the product. For this reason, products on the market typically have a short shelf life, as they are particularly susceptible to mould and yeast growth on their surfaces.

The formulations presented pH values ranging from 5.93 to 6.00, with no significant differences between the formulations.

The specific volume is important in determining quality because it is generally influenced by the quality of the ingredients used in the formulation. In the results

Table 2. Moisture, water activity (A_w) and specific volume of three treatments of bread (mean \pm SD)

Formulation	Moisture [g·(100 g) ⁻¹]	A_w	Specific volume
F1	34.68 ^b \pm 0.24	0.93 ^b \pm 0.00	3.98 ^b \pm 0.23
F2	30.49 ^a \pm 0.16	0.90 ^a \pm 0.00	3.34 ^a \pm 0.28
F3	29.66 ^a \pm 0.40	0.93 ^b \pm 0.00	3.67 ^{ab} \pm 0.21

^{a,b}different letters in the same column indicate a significant difference ($P \leq 0.05$) by Tukey's test

A_w – water activity, F1 – standard formulation; F2 – 30% sodium reduction; F3 – 50% sodium reduction

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Table 3. Colour analysis of tree treatments of bread (mean \pm SD)

Physical parameters	Core colour			Crust colour		
	a^*	b^*	L^*	a^*	b^*	L^*
F1	$-1.26^a \pm 0.08$	$13.46^a \pm 0.79$	$80.06^a \pm 1.40$	$14.75^b \pm 0.49$	$29.19^a \pm 1.06$	$44.99^a \pm 1.99$
F2	$-1.47^a \pm 0.15$	$12.23^a \pm 0.38$	$79.74^a \pm 2.32$	$14.19^a \pm 0.45$	$33.40^b \pm 1.28$	$50.42^b \pm 1.24$
F3	$-1.24^a \pm 0.16$	$13.51^a \pm 1.10$	$81.18^a \pm 1.24$	$14.49^{ab} \pm 0.19$	$30.59^a \pm 0.52$	$46.48^a \pm 0.39$

^{a,b} different letters in the same column indicate a significant difference ($P \leq 0.05$) by Tukey's test

F1 – standard formulation; F2 – 30% sodium reduction; F3 – 50% sodium reduction

presented, no difference was found between the samples that obtained sodium reduction, with F3 3.67 ± 0.21 presenting similar results to F1 and F2. According to Lynch et al. (2009), no significant differences in specific bread volume were observed across sodium chloride concentrations. Regarding the shrinkage index, Table 2 shows that the formulations did not differ significantly ($P > 0.05$).

Colour. The results of the colour analysis of the bread produced are presented in Table 3. It was found that the parameters lightness (L^*) and chromaticity a^* and b^* of the crumb did not vary significantly between the samples.

The chromaticity values a^* and b^* of the crust colour of sliced bread did not show significant differences. Breads F2 and F3 with reduced salt in their formulations showed a higher lightness value, L^* , resulting in a lighter product. While F1 showed a lower lightness value, L^* , resulting in bread with a darker crust than the other bread.

Thus, it can be seen that the colour of sliced bread is directly related to the ingredients contained or absent in the formulation. In this study, it was observed that F1 (44.99 ± 1.99) was darker than F2 (50.42 ± 1.24) and F3 (46.48 ± 0.39), which underwent salt reduction. Salt and sugar help to achieve a golden colour in bakery products (Pasqualone et al. 2019).

The Maillard reaction causes the darkening of the surface of sliced bread, and L^* values quantify its intensity. According to Pasqualone et al. (2019),

the reduction in salt content probably decreased yeast inhibition, resulting in a lower concentration of available sugars. Therefore, the Maillard reaction was less intense, resulting in a lower bread colour than in the control.

However, a study by Monteiro et al. (2021) showed that reducing salt content or using salt clusters did not result in noticeable colour differences compared with the control. Furthermore, a visual inspection by a baking expert did not detect any salt stains. Only after a detailed visual inspection were some soggy stains observed.

Sodium content. Sodium analyses were performed to confirm that the prescribed amount was maintained in the final product and that no losses occurred during processing. Table 4 shows the amounts of sodium found. Comparing standard formulation F1, which contained $608.54 \text{ mg} \cdot (100 \text{ g})^{-1}$ of sodium, with sample F2, which contained $432.06 \text{ mg} \cdot (100 \text{ g})^{-1}$ of sodium, resulted in a 29.0% sodium reduction. Comparing F3, which contained $303.27 \text{ mg} \cdot (100 \text{ g})^{-1}$ of sodium, resulted in a 49.8% reduction in sodium, values very close to those obtained with 30% and 50% reductions in encapsulated salt.

Sensory analysis. As shown in Table 4, the results obtained in the salinity intensity analysis were: F1 (3.63 ± 0.69) and F2 (3.77 ± 1.09); therefore, they did not present a statistical difference ($P < 0.05$) in perception, while F3 (1.89 ± 1.12) presented a difference about the others, being the one that had a 50% reduction in salt in the product as a whole.

Table 4. Sodium content and sensory perception of salinity in bread formulations (mean \pm SD)

Formulations	Sodium [$\text{mg} \cdot (100\text{g})^{-1}$]	Salinity sensory
F1	$608.54^c \pm 3.19$	$3.63^b \pm 0.69$
F2	$432.06^b \pm 5.43$	$3.77^b \pm 1.09$
F3	$303.27^a \pm 4.30$	$1.89^a \pm 1.12$

^{a-c} different letters in the same column indicate a significant difference ($P \leq 0.05$) by Tukey's test

F1 – standard formulation; F2 – 30% sodium reduction; F3 – 50% sodium reduction

Through this result, we can highlight that F2, in which a 29% reduction of NaCl was performed, did not present a difference with F1, demonstrating that the sodium encapsulation methodology that enabled the non-homogeneous distribution of salt in the dough, even effectively reducing the salt, did not present a different salt perception than F1.

This result was similar to that observed by Monteiro et al. (2021), who found that reducing sodium by adding salt to agglomerates improved the perception of salinity, making the product comparable to the control. Thus, the non-homogeneous distribution of salt agglomerates preserved the perception of salinity despite a 30% reduction in salt content. Salt agglomerates create 'salty spots' in the bread, generating a striking sensory contrast and intensifying the perception of salinity (Noort et al. 2012).

In the research by Beck et al. (2022), the use of salt encapsulated in carnauba wax allowed a 35% reduction in the amount of salt added to bread without compromising the perception of salinity in the final product. Similarly, Noort et al. (2010) reported that the non-homogeneous distribution of salt can intensify the perception of salinity, allowing the reduction of salt content without affecting its sensory perception.

It is related to the reduction of adaptation and gustatory response caused by continuous exposure of taste buds to salt (Xiong et al. 2020). Furthermore, using salt with an inhomogeneous distribution can accelerate the release of sodium from the food matrix to the tongue during bread consumption, intensifying the perception of saltiness (Li et al. 2020). Similarly, Mueller et al. (2016) observed a faster release of sodium in pizzas prepared with coarse-grain sodium chloride compared to the control, an effect proven in tests with a chewing simulator and sensory evaluations with tasters.

CONCLUSION

The results of this study showed that the inhomogeneous salt distribution in breads produced with salt encapsulated with xanthan gum added at the final stage of dough mixing can be used to increase the product's saltiness, allowing the salt to concentrate in spots throughout the dough rather than being evenly distributed. This resulted in 29% less salt being used, with no significant difference in saltiness.

The use of xanthan gum as an encapsulant did not cause any other changes in the bread, demonstrating its viability as a solution for salt reduction without requiring significant changes to the baking process.

REFERENCES

- Basso F.M., Mangolim C.S., Aguiar M.F.A., Monteiro A.R.G., Peralta R.M., Matioli G. (2015): Potential use of cyclodextrin-glycosyltransferase enzyme in bread-making and the development of gluten-free breads with pinion and corn flours. *International Journal of Food Sciences and Nutrition*, 66: 275–281.
- Beck P.H.B., Beluci N.C.L., Monteiro A.R.G., dos Santos Scholz M.B., Neto A.Á.M. (2022): Carnauba wax utilization in salt encapsulation: Application in bread. *Journal of Food Science and Technology*, 59: 3307–3311.
- Chen G., Ehmke L., Sharma C., Miller R., Faa P., Smith G., Li Y. (2019): Physicochemical properties and gluten structures of hard wheat flour doughs as affected by salt. *Food Chemistry*, 275: 569–576.
- Chiu N., Tarrega A., Parmenter C., Hewson L., Wolf B., Fisk I.D. (2017): Optimization of octinyl succinic anhydride starch stabilised $w_1/o/w_2$ emulsions for oral destabilization of encapsulated salt and enhanced saltiness. *Food Hydrocolloids*, 69: 450–458.
- Dischsen A.E., Monteiro A.R.G., Fukuda G.T., Marques D.R. (2012): Development of a breakfast cereal using waste from cassava processing industry. *Acta Scientiarum. Technology*, 35: 157–161.
- Guilloux M., Prost C., Courcoux P., Le Bail A., Lethuaut L. (2015): How inhomogeneous salt distribution can affect the sensory properties of salt-reduced multi-component food: Contribution of a mixture experimental design approach applied to pizza. *Journal of Sensory Studies*, 30: 484–498.
- Hendriksen M.A.H., Hoogenveen R.T., Hoekstra J., Geleijnse J.M., Boshuizen H.C., van Raaij J.M.A. (2014): Potential effect of salt reduction in processed foods on health. *The American Journal of Clinical Nutrition*, 99: 446–453.
- Israr T., Rakha A., Sohail M., Rashid S., Shehzad A. (2016): Salt reduction in baked products: Strategies and constraints. *Trends in Food Science & Technology*, 51: 98–105.
- Kloss L., Meyer J.D., Graeve L., Vetter W. (2015): Sodium intake and its reduction by food reformulation in the European Union – A review. *NFS Journal*, 1: 9–19.
- Li Y.L., Han K.N., Wan Z.L., Yan X.Q. (2020): Salt reduction in semi-solid food gel via inhomogeneous distribution of sodium-containing coacervate: Effect of gum arabic. *Food Hydrocolloids*, 109: 106102.
- Lynch E.J., Bello F.D., Sheehan E.M., Cashman K.D., Arendt E.K. (2009): Fundamental studies on the reduction of salt on dough and bread characteristics. *Food Research International*, 42: 885–891.
- Mohammadi M., Sadeghnia N., Azizi M.H., Neyestani T.R., Mortazavian A.M. (2014): Development of gluten-free flat bread using hydrocolloids: Xanthan and CMC. *Journal of Industrial and Engineering Chemistry*, 20: 1812–1818.

<https://doi.org/10.17221/46/2025-CJFS>

- Monteiro A.R.G., Nakagawa A., Pimentel T.C., Sousa I. (2021): Increasing saltiness perception and maintaining quality properties of low salt bread using inhomogeneous salt distribution achieved with salt agglomerated by waxy starch. *LWT – Food Science & Technology*, 146: 111451.
- Mueller E., Koehler P., Scherf K.A. (2016): Applicability of salt reduction strategies in pizza crust. *Food Chemistry*, 192: 1116–1123.
- Noort M.W.J., Bult J.H.F., Stieger M., Hamer R.J. (2010): Saltiness enhancement in bread by inhomogeneous spatial distributions of sodium chloride. *Journal of Cereal Science*, 52: 378–386.
- Noort M.W.J., Bult J.H.F., Stieger M. (2012): Saltiness enhancement by taste contrast in bread prepared. *Journal of Cereal Science*, 55: 218–225.
- Parenti O., Guerrini L., Cavallini B., Baldi F., Zanoni B. (2020): Breadmaking with an old wholewheat flour: Optimization of ingredients to improve bread quality. *LWT – Food Science & Technology*, 121: 108980.
- Pashaei M., Zare L., Khalili Sadrabad E., Abad A.H., Mollakhalili-Meybodi N., Abedi A.S. (2022): The impacts of salt reduction strategies on technological characteristics of wheat bread: A review. *Journal of Food Science and Technology*, 59: 4141–4151.
- Pasqualone A., Caponio F., Pagani M.A., Summo C., Paradiso V.M. (2019): Effect of salt reduction on quality and acceptability of durum wheat bread. *Food Chemistry*, 289: 575–581.
- Silow C., Axel C., Zannini E., Arendt E.K. (2016): Current status of salt reduction in bread and bakery products – A review. *Journal of Cereal Science*, 72: 135–145.
- Vieira A.H., Balthazar C.F., Rocha R.S., Silva R., Guimaraes J.T., Pagani M.M., Pimentel T.C., Esmerino E.A., Silva M.C., Tonon R.V., Cabral L.M., Freitas M.Q., Cruz A.G. (2020): The free listing task for describing the sensory profiling of dairy foods: A case study with microfiltered goat whey orange juice beverage. *Journal of Sensory Studies*, 35: e12594.
- Voinea A., Stroe S.G., Codinã G.G. (2020): The effect of sodium reduction by sea salt and dry sourdough addition on the wheat flour dough rheological properties. *Foods*, 9: 610.
- Wan Z., Khubber S., Dwivedi M., Misra N.N. (2021): Strategies for lowering the added sugar in yogurts. *Food Chemistry*, 344: 128573.
- Xiong Y., Deng B., Warner R.D., Fang Z. (2020): Reducing salt content in beef frankfurter by edible coating to achieve inhomogeneous salt distribution. *International Journal of Food Science and Technology*, 55: 2911–2919.

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